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ACHIEVING TOBACCO SMOKE-FREE ENVIRONMENTS, THE PROBLEM, AND SOME SOLUTIONS

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ABSTRACT

Tobacco smoke has long been recognized as a serious irritant and potential health hazard to non-smokers in the indoor environment. Various solutions to this problem have been implemented by many managers with both success and failure. This paper presents cases in different buildings where tobacco smoke was identified as an environmental irritant and illustrates different control strategies that did and did not eliminate the problem. Methods and results are detailed.

INTRODUCTION

There has been increased attention focused on achieving environments that are free from the air contaminants associated with environmental tobacco smoke (ETS). This has occurred in response to the 1986 Surgeon General's Report entitled, "The Health Consequences of Involuntary Smoking" and the National Academy of Sciences Report entitled, "Environmental Tobacco Smoke Measuring Exposures and Assessing Health Effects." These reports have both concluded that ambient tobacco smoke can and does cause lung cancer and other serious health problems for nonvoluntary smokers. This issue is not a new one and the authors have been involved with this aspect of indoor air quality investigations for a number of years, focusing on objectively determining the impact of smoking activities on nearby areas which are intended to be smoke-free. This paper presents a summary of the information we have gained from these experiences.

The control of any air contaminant, such as environmental tobacco smoke, can typically be treated by one of the five basic options of control: source removal, source modification, air cleaning, dilution ventilation or exhaust ventilation. This paper discusses the application of each of these approaches for achieving smoke-free environments in office-type buildings.

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SOURCE REMOVAL

From an engineering standpoint, the most efficient technique for achieving a tobacco-smoke-free environment is the elimination of smoking activity from the given environment. That is the trivial solution. This presentation therefore will focus on the applications of the other options either singly or in combination.

SOURCE MODIFICATION

The second option, source modification, refers in this discussion to the relocation of smokers from many locations to only one or a few specific locations to achieve a reduction in the number of areas directly impacted by ETS. This approach, by concentrating the number of smokers in fewer locations, may change the magnitude of exposures and rearrange the distribution of ETS but will not achieve a smoke-free environment if the area or areas where smoking is permitted is connected to an HVAC system which recirculates the return air to other locations in the building which are intended to be smoke-free.

Our testing efforts have demonstrated that the simple separation of smokers and nonsmokers within the same air space may reduce, but does not eliminate, exposure of nonsmokers to environmental tobacco smoke. This is also a major conclusion of the Surgeon General's report (1986).

Examples from our testing experience point out the problems with this approach. In one hospital cafeteria, about one-third of the area was designated "smoking" while the remaining two-thirds was designated as "nonsmoking." The impact of ETS was determined by measuring the concentration of respirable particulate matter (RSP), one component of ETS which provides a useful analytical indicator. These RSP concentrations were measured by a portable mass respirable monitor (using a piezoelectric quartz crystal for determining the relative RSP concentrations). In this situation, as with other cafeterias, the distribution of RSP was largely influenced by the airflow patterns created by the presence of exhaust fans in the food preparation area. The resulting distribution in this example consisted of elevated RSP concentrations over most of the cafeteria, especially in the nonsmoking area situated between the smoking area and the food service area. In another cafeteria arrangement, the nonsmoking area was located entirely between the food-serving line and the smoking permitted section. This geometry meant that the entire nonsmoking section, not just a portion of it, was impacted by the adjacent smoking activity. These examples point out the great difficulty in providing smoke-free environments in cafeterias because of the influence of the exhaust systems in the food preparation areas. For instance, if the smoking area were closer to the kitchen, then the nonsmokers on the food-serving line would be impacted by the nearby smoking. In both

these situations, because it was the intent of both hospital administrations to provide their employees and visitors with a smoke-free environment, smoking was entirely banned from these cafeterias. A major redesign of the ventilation system was not a viable option in these cases.

In two other cafeteria examples, the influence of a recirculating cooling system was demonstrated. In one system, there were four fan/coil units above the ceiling that only served the cafeteria. The air intakes for these four parallel systems were located in the ceiling near the food serving lines of the cafeteria with the return being to the cafeteria via three or four ceiling diffusers that are distributed the length of the room. The measurements of RSP in this situation demonstated that by keeping the room well mixed, the area concentrations rose uniformly throughout the room. The only difference between the nonsmoking and smoking areas was that the smoking area contained several higher peak RSP concentrations in the immediate vicinity of smokers. This HVAC system did not provide any observable reduction in the concentrations of RSP. The second example differed in that the nonsmoking area was more physically separated from the smoking area by enclosing walls. However, since there was not a separate ventilation system as well, the measured RSP concentrations in the nonsmoking area were again similar to those obtained in the smoking area.

AIR CLEANING

The possibility does exist, however, that the HVAC could remove the ETS air contaminants from the return air stream before recirculating all or a portion of this air back to occupied spaces. This approach leads to the third option, air cleaning, which refers to the use of equipment for removing the air contaminants from cigarette smoke as part of either the HVAC system or as an isolated installation near the site of the smoking activity. ETS is characterized not only by respirable particulates but also benzene, acrolein, N-nitrosamine, pyrene, nicotine decomposition products, and carbon monoxide. Air-cleaning equipment includes HEPA filters or electrostatic precipitators, which can remove the respirable particulate from the airstream, but have not demonstrated the ability to remove the volatile components, nor should they be expected to. Collection of volatile components would require the use of a granulated filter media capable of adsorption such as activated carbon or some type of catalytic system.

Research has shown that the semi-volatile components of ETS, which may initially be collected by the air-cleaning device (due to their adsorption onto the particulate matter), may be released into the airstream. The presence of these semivolatile components of ETS may then still be a source of potentially irritating odors to nonsmokers.

In one example evaluated, isolated ceiling-mounted electrostatic air cleaners were installed in hospital "day rooms." The use of this equipment did not yield a measurable improvement in reducing the concentrations of RSP as compared to when the equipment was not in use. Even if there had been a measurable reduction in RSP concentrations, this would not be sufficient to characterize the space as smoke-free, because there would be no reduction in the volatile components of ETS which were still being released into and recirculated around the room. Electrostatic precipitators (ESPs) require frequent cleaning to maintain their effectiveness and minimize the release of odors from previously collected material. The ESP installations observed by the authors have typically not been receiving cleaning on a regular or frequent basis. Installing the air-cleaning device in the HVAC system as opposed to merely locating it in ceiling above a smoking area may increase or decrease the likelihood of frequent periodic cleaning depending on who is responsible for this maintenance. In-duct installations possess the same problems. Articles have been written which attempt to assess the effectiveness of this approach based on chamber studies (Allen H. Frey, 1985). In the opinion of the authors, the overall effectiveness of this approach in controlling both RSP and odors has yet to be proven.

DILUTION VENTILATION

One difference of in-duct installations of air-cleaning devices, as compared with site specific installations, is that they may further reduce ETS concentrations by diluting the air contaminants into a larger volume of air. The down side of this is that a larger portion of the building may be impacted. This brings us to a discussion of the next basic option for the control of air contaminants -- dilution ventilation. Dilution ventilation refers to dilution of contaminated air with uncontaminated air in a general area, room, or building for the purpose of health hazard or nuisance control (American Conference of Governmental Industrial Hygienists, 1984). Since ETS has now been identified as a cause of cancer, the question can be raised as to whether any amount of dilution would achieve a zero threshold of exposure. As stated in the Surgeon General's report, "The first response to the identification of a carcinogen in the work environment should be to eliminate that exposure. It is only when elimination of the exposure is not possible that we should explore establishing acceptable levels for the worksite." One approach for dilution ventilation would be to determine what ventilation rates would be required so that visitors to an area would not object to the odor of tobacco smoke. Work of this nature was performed by Cain and Leaderer (1982) who reported that ventilation rates up to 30 cfm per occupant were not sufficient to achieve a "75-80% acceptance of the odor by visitors" which was their criterion for acceptability. They concluded that "a ventilation rate as high as 100 cfm per smoking occupant might be necessary" to meet their criterion of acceptability in situations where smoking occurs more or less continuously.

This article also reported that "surfaces in an enclosed room, seem to be important sinks for tobacco smoke indoors" and, "that absorbed particles may carry condensed volatiles which could evaporate over time, thereby imparting a lingering odor". To prevent this contamination of surfaces in a smoking area, it is recommended that the preferred method of control be the application of local exhaust ventilation.

EXHAUST VENTILATION

This approach is an embodiment of one of the basic principles of industrial hygiene, the collection of air contaminants as close to the source as possible. This approach minimizes the air volumes required and maximizes the collection efficiency. This approach also requires that quantities of make-up air equal in volume to that being exhausted be supplied to the vicinity of the exhausted area. Aside from the complete elimination of smoking activities, this approach has the greatest potential for achieving tobacco smoke-free environments. To achieve the desired goals there are certain basic rules that need to be followed. The first requirement is the designation of a specific location as a smoking lounge. This location needs to be a physically enclosed space that is separate from other areas. This includes isolation from the rest of the recirculating air-handling system to prevent the transport of ETS air contaminants to other locations in the building. This can be achieved by blocking the return-air ductwork located in this area and replacing it with exhaust registers that transport the air contaminants directly to the outside for discharge. The exhaust fan for this system should also be located outside or as close to the outside as possible so that the ductwork transporting the air contaminants is under negative pressure in the building. This is important because if the ductwork is not leaktight and under positive pressure, there can be leakage of air contaminants back in the return plenum. It is also important to locate this point of discharge away from any air intakes to minimize the possibility of reentrainment. The location of both the exhaust register and the makeup supply air is critical. It is crucial that they be located so as to minimize any short circuiting of the supply air directly to the exhaust. One example of short circuiting was observed at a school where smoking was permitted in one of the two teacher's lounges. In this situation, the exhaust register was located in the ceiling near a corner of the room and the make-up air came through a grille in the door to the room. Unfortunately for the effectiveness of the system, the door to the room was located in one of the walls nearest the exhaust register thereby eliminating much of the potential benefit of this exhaust ventilation. A more effective geometry for the collection of ETS air contaminants in this situation would have been to have the exhaust register still in the ceiling but near the wall furthest from the location of the supply air. In a situation where there is a ducted supply system, collection efficiencies would be maximized and the greatest likelihood of achieving a smoke-free environment would occur

if the make up air were supplied near floor level and at several locations around the room. This strategy has yielded successful results for one of our clients. The exhaust register should be in the ceiling, either in the center of the room or as close to the maximum concentration of smokers as possible.

Another advantage of exhaust ventilation, as compared with dilution ventilation, is that with the proper placement of exhaust registers and supply grilles, it is possible to achieve plug-flow through the space. This situation will achieve the maximum benefit of air contaminant removal for given quantities of airflow. This is particularly important both for energy conservation and in situations where the "smoking lounge" is a multiple-use space and will be occupied by non smokers as well as smokers.

CONCLUSIONS

The easiest approach for achieving a smoke-free environment for workers would be to eliminate smoking entirely from the building where they work. Exposures to air contaminants from ETS can be reduced by means of air-cleaning techniques or dilution ventilation, however, to be effective in achieving a smoke-free environment, there needs to be a local exhaust ventilation system which both isolates a smoking area from all other areas and discharges the ETS air contaminants outside and away from all air intakes.

REFERENCES

Surgeon General's Report. The Health Consequences of Involuntary Smoking, U.S. Public Health Service. 1986. Page 332.

Committee on Passive Smoking. National Research Council, National Academy of Sciences. Environmental Tobacco Smoke Measuring Exposures and Assessing Health Effects. 1986. Page 245.

Allan H. Frey. Bulletin of Environmental Contamination and Toxicology. Modification of Aerosol Size Distribution by Complex Electric Fields. June, 1985. Pages 850-857.

American Conference of Governmental Industrial Hygienists. Committee on Industrial Ventilation, P.O. Box 16153, Lansing Michigan, 48901. Industrial Ventilation, A Manual of Recommended Practice, 18th Edition. 1984.

William S. Cain and Brian P. Leaderer. Ventilation Requirements in Occupied Spaces During Smoking and Nonsmoking Occupancy. Environment International, Vol. 8. Pages 505-514. 1982.